United Nations Educational, Scientific and Cultural Organization.

Section of Cultural Heritage

REPORT

DOCUMENTING

Cultural Landscape and Archaeological Remains of the

BAMIYAN VALLEY

Bamiyan Cliff including niches of the 38 meter Buddha, seated Buddhas, 55 meter Buddha and surrounding caves

By Dr. Mario Santana Quintero

Leuven, July 2003

CONTENTS

This report contributes to the series of assessment implemented in the analysis phase for the consolidation of the cliff face at Bamiyan. This effort is currently funded by the UNESCO/Japanese Funds-in-Trust.

This report consists in a set of measured representations of the current condition of the Bamiyan Cliff, concentrating in mapping the niches of the Large Buddha (55 meter Buddha) and Small Buddha (38 meter Buddha).

The '*Cultural Landscape and Archaeological Remains of the Bamiyan Valley*' (WHC-UNESCO, 2003)[1] has been recently included in the World Heritage list by UNESCO. This site has a universal value to humanity and it is a positive example of the efforts of the international community in the protection of monuments that has been damaged by human action.

Furthermore, this mission has been organized by Christian Manhart (UNESCO section of Cultural Heritage) and Professor Michael Jansen (RWTH Aachen Germany). As well as, the logistic support of the Afghan Ministry of Information and Culture and the regional UNESCO office in Kabul.

The measurements of the site were carried out with the cooperation of the engineer A. Fahim from the Department of historic building (Afghan Ministry of Information and Culture).

2. OBJECTIVES

The role of the metric survey tools chosen for this recording task was focused in producing measured representations that include a vector and image based record of the geometry and texture of the fabric of the subject and its context.

The resulting product presents the current state of conservation of the niches, which will be used for the classification and removal of the fragments of stone remaining from the explosion to a safer place.

Moreover, this report presents the field work carried out in a period of three-weeks in situ. Making emphasis in the methodology used, the results, recommendation for future documentation efforts and monitoring of the site.

The tools used are conventionally apply in geodesy and they have been adapted to the needs of the specific area and the available resources, making emphasis in the use of optimal and sustainable methods for the current condition of this country in terms of political, legal, and practical infrastructure for protecting built heritage.

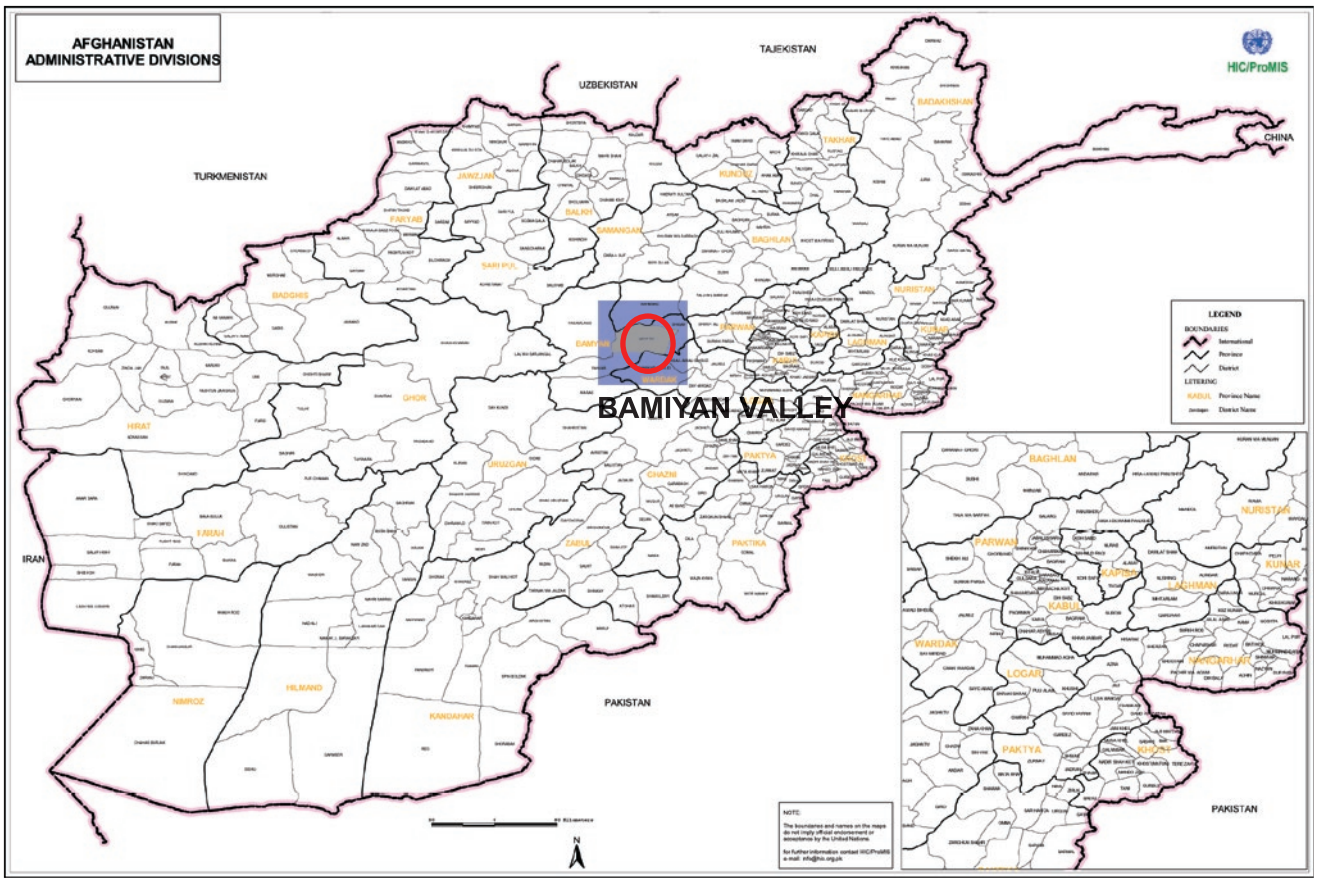


Figure 1: location of the Bamiyan valley in Afghanistan. http://www.aims.org.pk (last visited 06/2003)

2.1 Documentation tasks

2.1.1 Related to the general context:

Coordinate reference system (UTM): control of the UTM linked coordinate reference system prepared in July 2002 mission. Reparation of new fix points around the niches and other relevant targeted positions to be measured.

Topographic and urban features map of the immediate surroundings of the niches for referential purposes: horizontal projection. Showing access road, immediate structures to the site, other important landmarks, and a topographic map with contour interval of 1 m.

2.1.2 Specific sites: large and small Buddha:

Detailed topographic map displaying the amount and size of the rubble in the niches, identifying and classifying the most significant fragments in size and shape: 3D topographic map, horizontal projection with contouring (interval 0.1 m), elevation plan and a vertical cross section.

Measured photographic record using rectified images of the niches for referential purposes: elevation and horizontal projection

2.2 Mission schedule

On-site work 17june - 1 july 2003 (Bamyan)
Preliminary report: off-site work: 1 to 5 July 2003 (Kabul)
Final Report: 14 july 2003 (Europe)

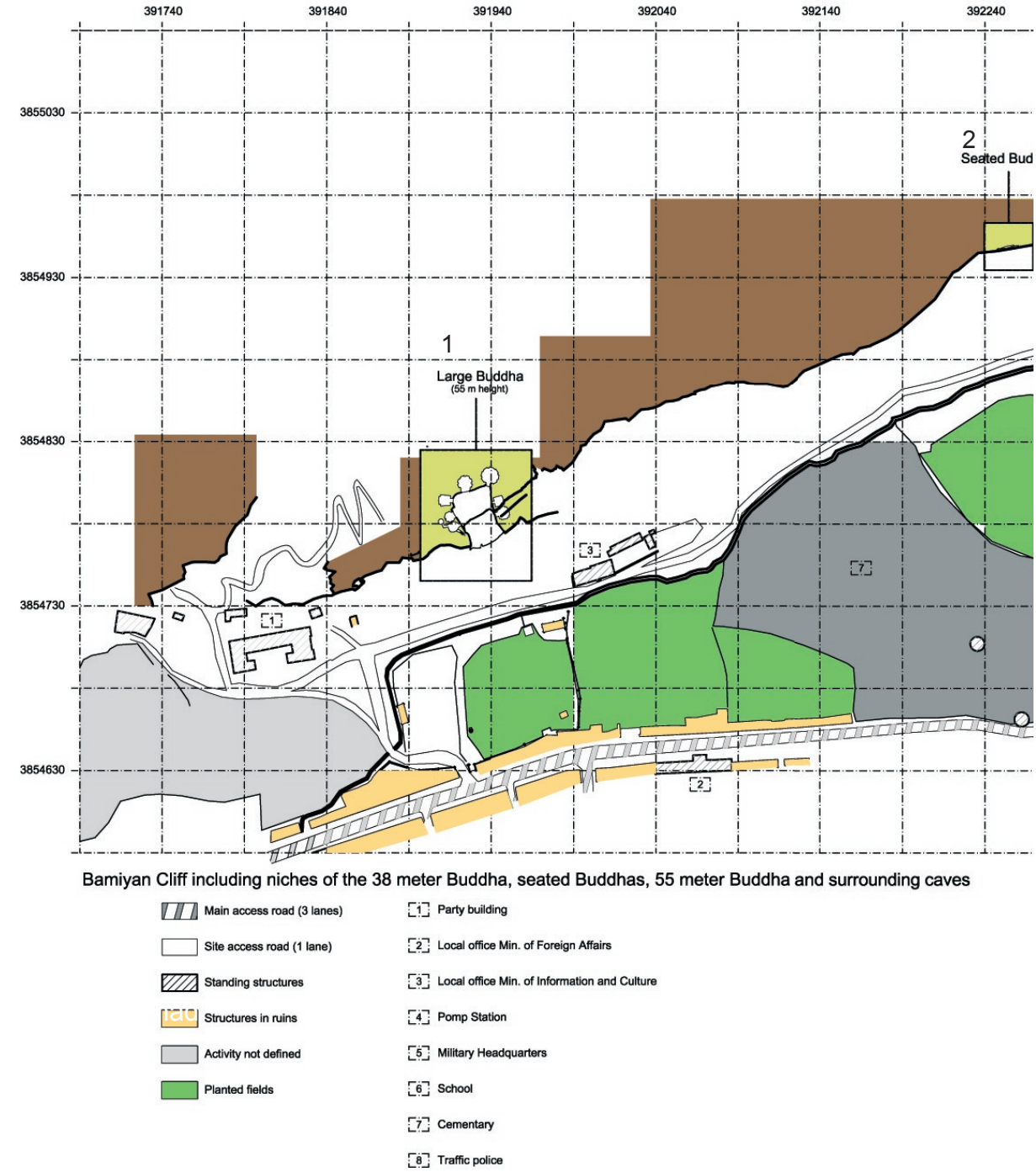
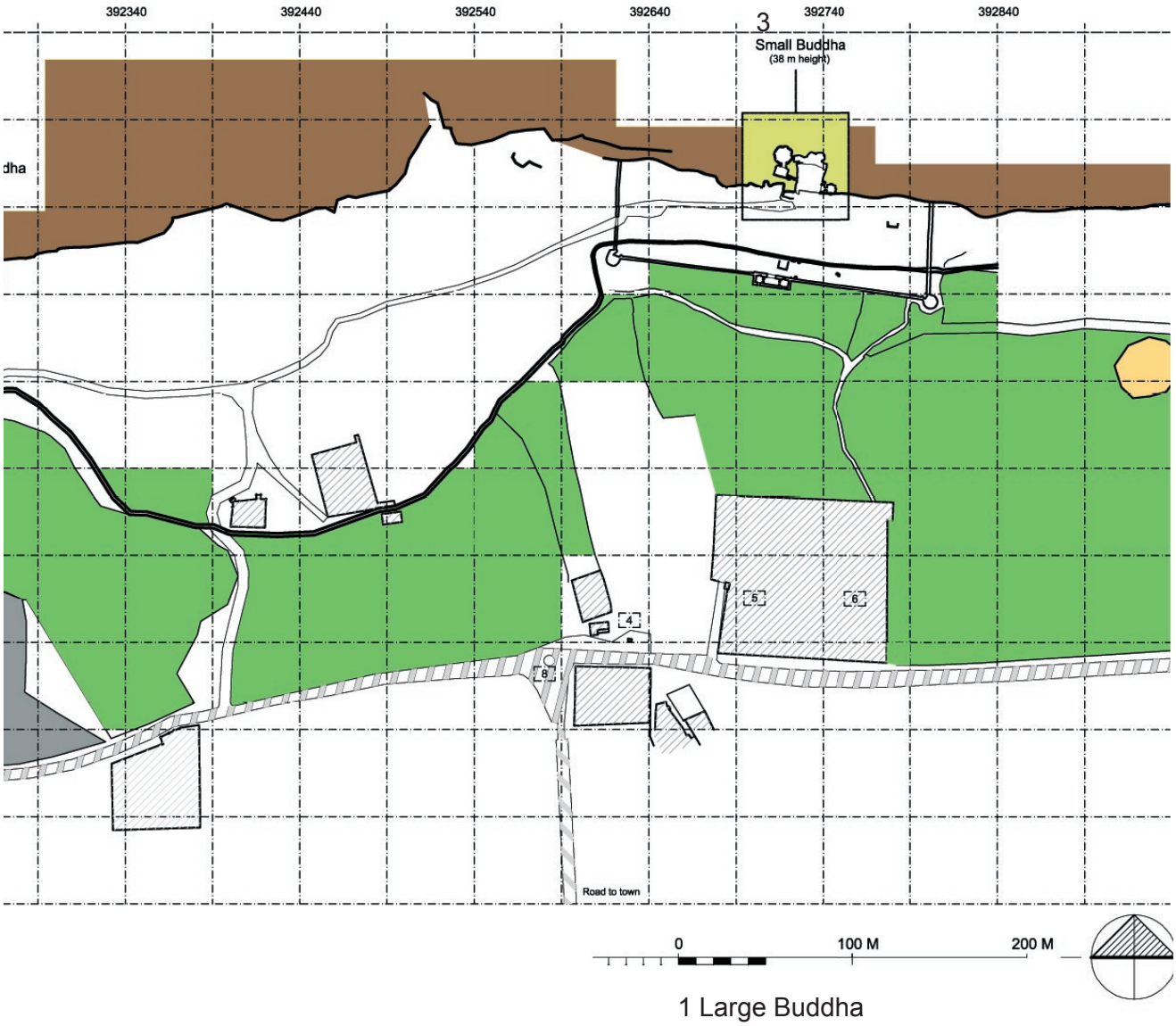


Figure 2: ground map and panorama of the Bamiyan cliff. Author.



1 Large Buddha
2. Seated Buddha
3. Small Buddha

2.3 Digital formats for final measured dataset

Digital and plotted maps will be deliver at the end of the mission to UNESCO Kabul (A3 format) for immediate use in further works of removal and classification - a more detailed report and maps will be delivered to UNESCO headquarters in Paris (A3).

Maps:

General site map
Specific site maps: large and small Buddha
Ground map of the niches, including the digital Terrain model and a rectified image: large and small Buddha
Elevation (vector and image-based): front of the niche of the large and small Buddha.

3. SITE BACKGROUND

'The cultural landscape and archaeological remains of the Bamiyan Valley, located 233 km from Kabul. The valley is 15 km long and not more than 3 km wide, at lies at an altitude of 2500 m' (Knobloch, E. 2002, pp.88-89)[2].

'*Bamiyan was, between the sixth and ninth century, the capital of a small kingdom which was part of a confederation of Turkic and Hepthalite principalities between the eastern borders of the Sasanian empire and the Punjab in the south-east. It was conveniently situated halfway between the important cities of Balkh and Kapisa on the caravan route linking India with Bactria and Transoxania'* (Knobloch, E. 2002, pp.88-89)[3].

The two standing Buddhas statues (small and large) are a '*testimony'* (WHC-UNESCO, 2003)[4] of a irreversible action of destruction by human action in March 2001.

The measured plans, prepared in this report not only will contribute to the creation of a permanent record of its present, but to the analytical assessment of its current condition and understanding of its authenticity, both of which encourage the works for their protection.

'*The small Buddha (38 m high) was the first to be sculptured in these cliffs, sometime during the 3rd or very early 4th centuries A.D.. The figure was carved out of the face of the sandstone cliff and then covered with a mixture of mud and wheat straw in which the features and drapery were modelled. This in a turn was smoothed over with a very fine plaster made from gypsum (gatch) which was painted'* (Dupree, N.H., 1977, p. 156)[5].

Moreover, '*the large Buddha, 55 m high, was also carved from the face of the cliff but here the drapery, instead of being molded on the figure, was formed by draping ropes over the figure which were then covered with the mud and straw mixture. Several series of small holes made by the wooden plugs which held the ropes in place are clearly visible today*' (Dupree, N.H., 1977, p. 163)[6].

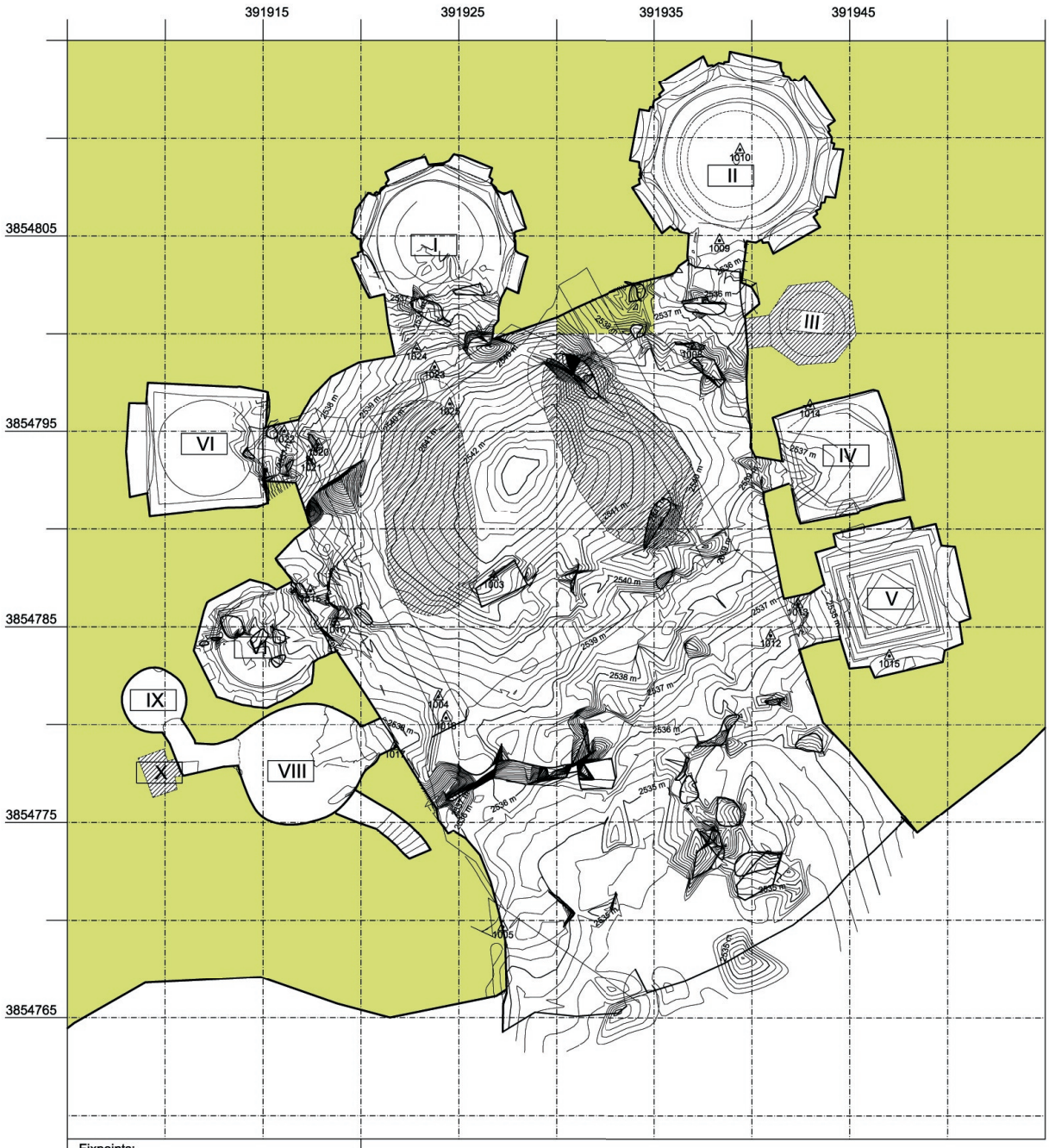
Beside the buddha's statues, the site contains a numerous of '*Buddhist monastic ensembles and sanctuaries*' (WHC-UNESCO, 2003)[7] or '*grotto-sanctuaries*' (Bruno, A. 1996, p. 27)[8] carved into the rock. Furthermore, evidence of ancient Islamic settlements is spread all over the site.

4. IMPLEMENTATION

4.1 Equipment used

Hardware:

- TCR307 Leica Total Station: capable of measuring without reflector to a range of 80 m.
- Sony Vaio model PCG-GRX316MP notebook with a Pentium IV processor, 30 GB Hard disk, 16x CD-Writer, and a screen of 16" for AutoCAD and other graphic software.



Fixpoints:

ID	East (m)	North (m)	Height (m)
1003	391926.776	3854787.557	2542.454
1004	391923.952	3854781.431	2540.398
1005	391927.119	3854769.713	2536.241
1006	391944.392	3854779.543	2536.541
1007	391914.707	3854772.052	2561.872
1008	391936.939	3854799.333	2538.359
1009	391938.34	3854804.746	2535.948
1010	391939.39	3854809.384	2535.31
1011	391935.116	3854811.832	2536.586
1012	391940.961	3854784.557	2536.655
1013	391942.338	3854786.168	2536.611
1014	391942.975	3854796.303	2537.918
1015	391917.388	3854786.827	2538.877
1016	391918.685	3854785.283	2539.241
1017	391921.765	3854778.877	2538.483
1018	391924.338	3854780.339	2539.874
1020	391917.818	3854794.352	2538.883
1021	391917.45	3854793.509	2538.753
1022	391916.081	3854794.995	2538.005
1023	391923.756	3854798.313	2539.909
1024	391922.841	3854799.246	2539.088
1025	391924.525	3854796.419	2541.242
1026	391927.841	3854804.57	2537.381

These areas have been digitized from a plan by Fango, R. 'Dossier Afghanistan' ANA FKH 32, Dec 2001. P. 30. Currently they are cover by rubble

0 10 M 20 M

Contour Interval= minor 0.5 m major 2 m.
Grid interval: 5 m

Technical specifications of the digital terrain model:
Number of triangles: 8050
Mean elevation: 2537.73 m
Minimum triangle area: 0.00 m
Maximum triangle area: 7.92 m
2D surface area: 892.27 m2
3D surface area: 1241.51 m3
Minimum grade: 0.60 %
Maximum grado: 1409435.86 %
Average grade: 472.54 %
Cut Volume: 5,147 m3
Fill Volume: 83.74 m3
Net: 78,6 m3
Reference datum for volume calculation: 2535.35 m.

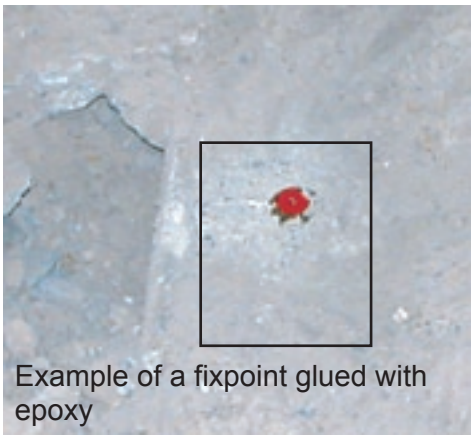

Example of a fixpoint glued with epoxy

Figure 3: ground map of the Large Buddha. Author.

- Nikon Coolpix 5500 Digital Camera with 5 MP resolution

Software:

- AutoCAD Land development desktop r3 for CADR processing and Digital Terrain Modeling generation to create representations of the topography and architecture of the measurements collected with the total station.
- AutoCAD Raster Design: a plug-in to AutoCAD that enables the user to rectified plan parallel and aerial photographs directly into the CADR drawing.
- Adobe Photoshop 7, a program for processing of digital images produced by the camera and other raster images work.
- Photomodeler 4.0: photogrammetric application
- PhotoGram Pro: for rectification of images (developed by B. Van Genechten for this work)

4.2 Site reference system

A reference system has been measured and calculated using a hand held GPS unit. A first reading was perform in the old ST1001 prepared during july 2002 mission on top of a piece of concrete 50 m. from the niche of the large Buddha, this UTM reading was assumed as starting position for the system, including altitude (see figure).

Using the same GPS unit, a second position, around 60 m from the first was performed to calculate the bearing or orientation to the absolute north. This reading took place in a dwell located 100 m southwest of the large buddha's niche (see figure).

ST1001 GPS Readings: UTM region 42 S:

East (M)	0391940
North (M)	3854734
Height (M)	2534

Dwell located southwest of the large buddha GPS Readings: UTM region 42 S:

East (M)	0391928
North (M)	3854657
Height (M)	2529

Subsequently, the system was transported to the Small Buddha using a set of temporarily interval points, this action has certainly has an impact in the precision of the system affecting to a range of centimetres.

Locally in each site (small and large Buddha's niches) a set of at least 5 fixpoints were made covering the niche using a rounded effloresce red painted plates glued to the stone using epoxy, the idea was to avoid damaging the material of the remainings (see figure). These plates are strong but they might be removed easily in the future.

4.3 Context map

A general context map including a hypothetical outline of the cliff outskirts, planted fields, access roads, and irrigation main channel, standing structures of relevance, structures in ruins and other relevant features were measured.

This map could be use for preparing a more advanced urban morphology map that can be use to monitor and understand both the ownership around the Buddha and the access to the sites.

More relevant to the project it can be use to identify and area for classification of the rubble extracted from the site.

Figure 4: ground map of the Small Buddha. Author.

4.4 Large Buddha:

4.4.1 Specific site context map

This map covers and area of approximate 50 m radius from the Large Buddha, identifying the planted fields, ruins and other standing structures, irrigation system, access roads, and other relevant features.

Furthermore a digital terrain model has been prepared from topographic measurements taken on the site. This model has a minor contour interval of 0.5 m and a major of 2 m.

This map can be useful to establish the requirements for accessing machinery to remove the fragments on the niches.

4.4.2 Ground plan

A ground plan was measured presenting the different side chambers connected to the niche. This horizontal section has a variable datum, depending on the needs of

Bamiyan cliff: Large and Small Buddha

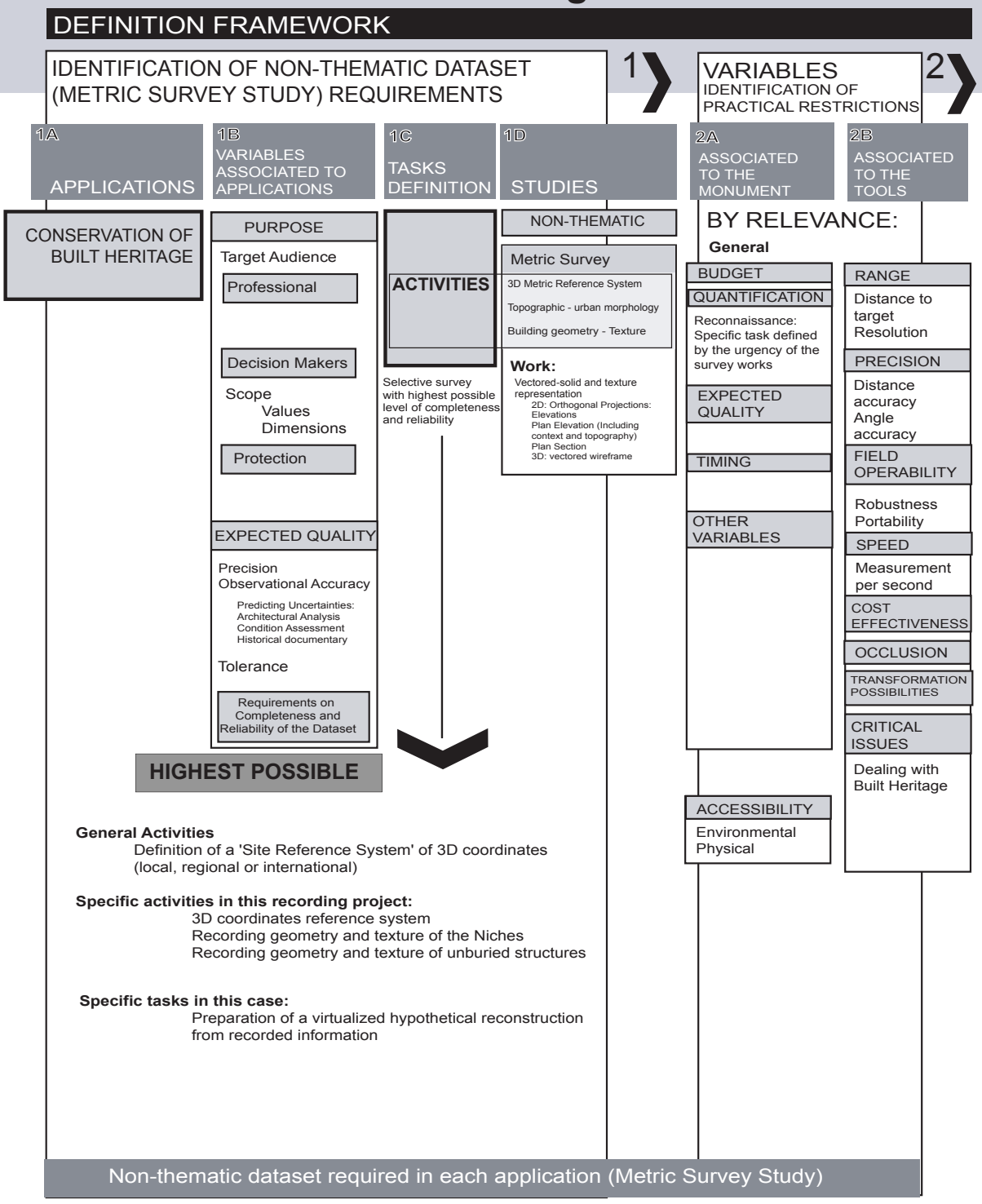
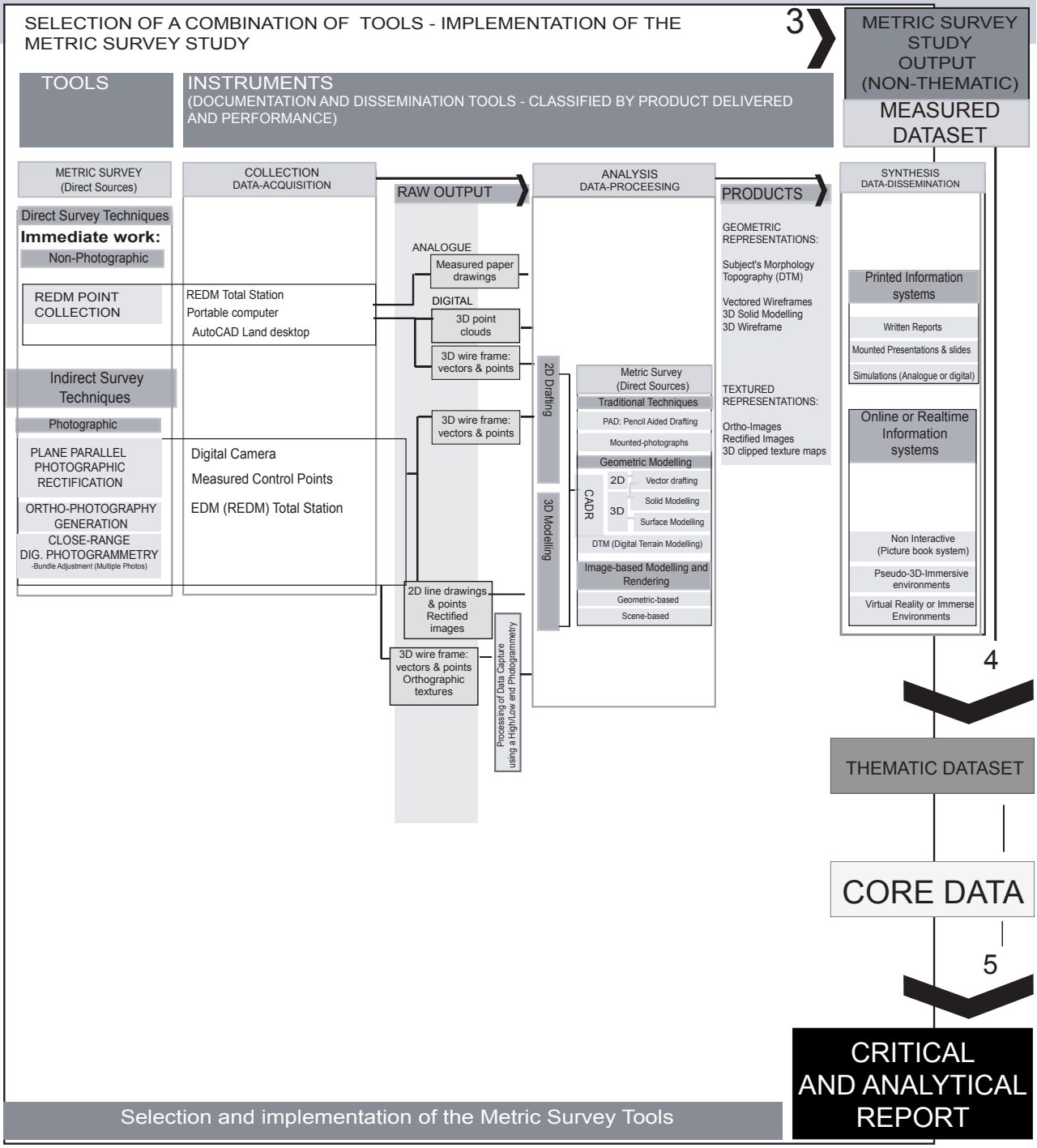


Chart 1: application framework applied to this case.

FRAMEWORK: SELECTION OF TECHNIQUES IN PREPARING THE METRIC SURVEY MEASURED DATASET

SELECTION FRAMEWORK



presentation the datum has been adapted to each room (see figure 3, p. 10).

4.4.3 Digital terrain model of the niche:

Topography: limiting the area to calculate the topographic model of the rubble left from the explosion, using a height reference from the northeast room. The limit of the model covers from selected in the rooms, the shape of the niche when touching the rubble and one meter south of the fence. Large stones shape is simplified with at least four measured points.

4.4.4 Wireframe: geometric representation of the shape of the niche.

A north front elevation has been prepared using rectified photography to identify the height, dimension and shape of the remaining elements.

4.5 Small Buddha:

4.5.1 Specific site context map

The context map is contained within the limits of the fortress surrounding the small Buddha. It presents the main features of this area, including irrigation system, planted fields, outskirts of the mountain cliff, and major fragments that had fallen outside the niche.

Furthermore a digital terrain model has been prepared from topographic measurements taken on the site. This model has a minor contour interval of 0.5 m and a major of 2 m.

This map can be useful to establish the requirements for accessing machinery to remove the fragments on the niches.

4.5.2 Ground plan and levels

A ground plan was measured presenting the different side chambers connected to the niche. This horizontal section has a variable datum; depending on the needs of presentation the datum has been adapted to each room. Due to the amount of rubble, one of the chambers located at the west front of the Buddha was inaccessible for measurements.

Furthermore, the different chambers located west to the niche and at three different levels were measured. The first level has been included in the ground plan. A horizontal section has been trace at the datum of each level to provide an overview of the shape.

4.5.3 Digital terrain model niche:

Topography: limiting the area to calculate the topographic model of the rubble left from the explosion, using a height reference from the northeast room. The limit of the model covers from selected in the rooms, the shape of the niche when touching the rubble and one meter south of the fence. Large stones shape is simplified with at least four measured points.

4.6 Definition framework in the selection of metric survey tools to acquire the geometry and texture of the site

4.6.1 Applications

In this case, and according to the needs of the project, the use of metric survey tools have been concentrated in preparing a ‘measured dataset’ that can be use for preparing a conservation plan for immediate interventions in protecting the physical appearance of the site after the destruction in march 2001 (see Chart 1, p. 11-12).

The target audience of this application is mainly professional. Making emphasis in the use of metric survey representations to prepare a diagnosis and therapy aimed at protecting the integrity of the fabric of the site.

Expected Quality and task definition

The 'metric survey study' is composed of measured representations with a reliable completeness of information and that are of the highest possible quality (see chart, p .).

Variables in the identification of restrictions in the use and selection of metric survey tools

The variables are ordered according to their relevance in the application (See Chart, p.).

Budget

The metric survey tools used in the works of documentation of this site were selected because of being cost-effective according to the limited budget assigned to the documentation work, which also includes archaeological studies and the study of the condition of the monument.

This variable associated to the monument affects the selection of tools that can effectively deal with:

Cost-effective, speed-range, field operability and the level of precision: they should be economically suited to the defined task.

Transformation possibilities: of the dataset collected to be use in different representations should be possible to transfer to other computer applications.

Quantification

This variable is important to this case, because the amount of information recorded of the actual state of the tomb will affect both the effectiveness of the conservation plans in calculating the extend of the works required for its protection.

During the mission, the works was concentrated in achieving these tasks, taking into consideration the available time and local available facilities.

This variable associated to the monument affects the selection of tools that can effectively deal with: range of the instrument should be sufficient to measured without reflector the highest areas of the cliff and niche, as well as, the field operability capabilities of the tool should be sufficient to operate under battery power for a extended period of time.

Furthermore, transformation possibilities of the dataset collected to be use in different applications, level of precision should be sufficient for the task, speed should be sufficient to carry out an useful survey, adjustments-corrections are of minor importance, and the capacity of the tool to deal with critical issues in recording built heritage.

To address these problems, a REDM total station was chosen that could deliver sufficient range, speed and field operability capacities for a limited budget.

Expected quality

This variable play an essential role in determining the level of completeness required in the metric survey.

The quality of the 'measured dataset' is defined by the '*degree of engagement with the fabric*' (Clark, K., 2001, p.76)[9] of the site and the level of verification required from

historical documents.

This base record will be used in 'analytical representations' to illustrate the chronology of the site, such as '*phase plans, 3D reconstructions, and cut away drawings*' (Clark, K., 2001, p.83)[10].

This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications in the field of studying the structural behavior of the monument, level of precision, speed-range, field operability and their capacity to deal with critical issues in recording built heritage.

Expertise

The tools selected has been already tested and used by the experts of the mission, so no particular requirements were associated to this variable.

This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications, level of precision, speed-range, field operability and their capacity to deal with critical issues in recording built heritage. But especially attention should be concentrated in their requirements in adjustments-corrections.

Timing

This variable had a major impact in the selection of the tools and execution of the metric survey. The metric tools selected should deliver sufficient data in a relative short time.

This variable associated to the monument affects the selection of tools that can effectively deal with: cost-effective, transformation possibilities of the dataset collected to be use in different applications, level of precision, speed-range, deal with occlusion interfering with the survey, adjustments-corrections required, field operability and their capacity to deal with critical issues in recording built heritage.

Accessibility

The particular remote location of the niches is an important variable that was taken into account for the selection of the tools used to measure the monument. The tool should be easy to transport and should be able to operate with battery supply (see quantification).

This variable associated to the monument mainly affects the selection of tools according to: speed-range and field operability.

Other variables

Since the project was made within the framework of an official UNESCO mission authorized by the Afghan Ministry of Information and Culture, accessibility was not restricted.

The training of an engineer can be included as a variable to consider, a lot of effort was made to make accessible the procedures and tools used in preparing the measured dataset, this on the one hand has certainly limit a bit the action of the recorder but it also ensures the successful transitions of the methods to staff working with these tools in the mission.

These variables associated to the monument affect the selection of tools that can effectively deal with: transformation possibilities of the dataset collected to be use in different representations, level of precision, speed-range, deal with occlusion interfering with the survey, adjustments-corrections required, field operability and their capacity to deal with critical issues in recording built heritage.

Figure 5: (1) Detail of a target for rectified photos and a fixpoints glued with epoxy (2) measuring the shape of the large buddha (3) measuring a room with the reflectorless feature. Author.

4.7 Recording methodology: explanation of selected metric survey tools

4.7.1 Reflectorless Electronic Distance Measurement devices (Point collection or tracing)

A 'reflectorless electronic distance measurement' device or 'total station' provides the traditional measurements 'mode' by projecting an infrared beam to a prism rod (reflector), as well as the reflectorless 'mode' by projecting a laser beam to a surface up to 80-200 m. from it (the current instrument used, Leica TCR307 provides up to 80m range) (see chart 2, p. 19).

A REDM device or total station operates without the use of a reflector and *'has the advantage of rapid targeting and access to remote targets*' (Clark, K., 2001, p.82)[11].

Furthermore, this action permits the machine to calculate the three-dimensional co-ordinates of a point using the geodetic information recorded, which includes the horizontal and vertical angles, horizontal and absolute distance to the measurement, and the different heights between the station and the targeted point.

In this application a 'reflectorless electronic distance measurement' device or 'total station' is used to record points in order to define an entity.

The phase of work of this tool consists of: data-collection, data-processing, verification and exporting.

Data-collection: involves preparing a network of fixpoints (bench-mark or standpoint) covering the entire site to establish a 'site reference' system.

Subsequently, network points measured and a least square calculations are performed for increasing the precision of the fixpoints.

After the REDM device is properly levelled to a fixpoint measuring point and orientated to a the base bearing angle to a second known station from the network just created, recording starts by defining and measuring a series of points (density of the survey) aimed at defining the targeted entity for further processing off-site work. These measurements are store in the memory of the machine and later transfer to the computer off-site.

Furthermore, a sketch or photographs of the situation should be prepared to mark the measurements, the machine permits the operator to insert a Point ID (alphanumeric or numeric characters) or in more advanced applications a code.

Data-processing: the measured points stored in the memory of the Total Station are transferred to the computer using communication software that delivers them into different formats containing 3D coordinates that can be read by a CADR or DTM application (e.g. DXF).

Subsequently, this cloud of points is identified in the CADR application space and 3D vectors are used to define the targeted entities conforming the subject's geometry.

In more advance applications, the readable coordinate file format contains codes appointed and predefined previously to the survey that can be read by the CADR and DTM application, in order to generate automatically the vectors connecting the measurements and produce a wireframe.

The resulting product is a wire frame of vectors and points that can be further used in photographic techniques, such as rectified photography to further digitise the geometry of the object.

Verification: the processes of controlling the measurements can be performed by checking the output on-site and using analogue theodolithe or photogrammetry technqies

The improvement required to the dataset of the survey can be performed by adding a higher density of point collecting adding more measurements in situ or implementing complementary techniques.

Exporting: the output consists of a 3D point cloud and wire frame CADR drawing format and a 3D Digital Elevation Model (contour lines and/or 3D mesh) if a DTM application is used.

Furthermore, an ASCII file containing of a list of coordinates from the measured records can be obtained.

4.7.2 Plane parallel photographic rectification

Plane parallel photography is a highly effective technique to generate a correct image-based representation of a fully or roughly flat plane; this tool can be use if the following conditions are available:

- The surface should be flat, not irregular. Nevertheless, depending on needs the recorder can use a certain degree of assumption about the irregularities of the surface (in the case of the niches this technique is used for referential purposes)
- The camera should be roughly or absolute parallel to the surface to record.
- An external reference system should be implemented to be able to acquire the scale of the object and reduce the distortion of the photograph.
- Overlapping of at least 30% is required for recording the surface, if multiple photographs are required

The objective of rectified or plane-parallel photography is to produce a roughly or absolute '*true-to-scale photographic image/ print of an object such as the facade of a building*' (ICOMOS, 1990, p. 54)[12] (see chart 3, p. 20).

Data-collecting: preparing a reference system using targets for the scale and to reduce distortion thus achieving a parallel position to the wall rectification:

A horizontal reference system: made by hand measuring tools and a levelled rope. Or using external or natural targets for measuring with a theodolithe or total station (REDM Total Station TCR 307 Leica).

A vertical reference system: made by hand measuring systems, such as plumbs. Or using external or natural targets for measuring with a theodolithe or total station.

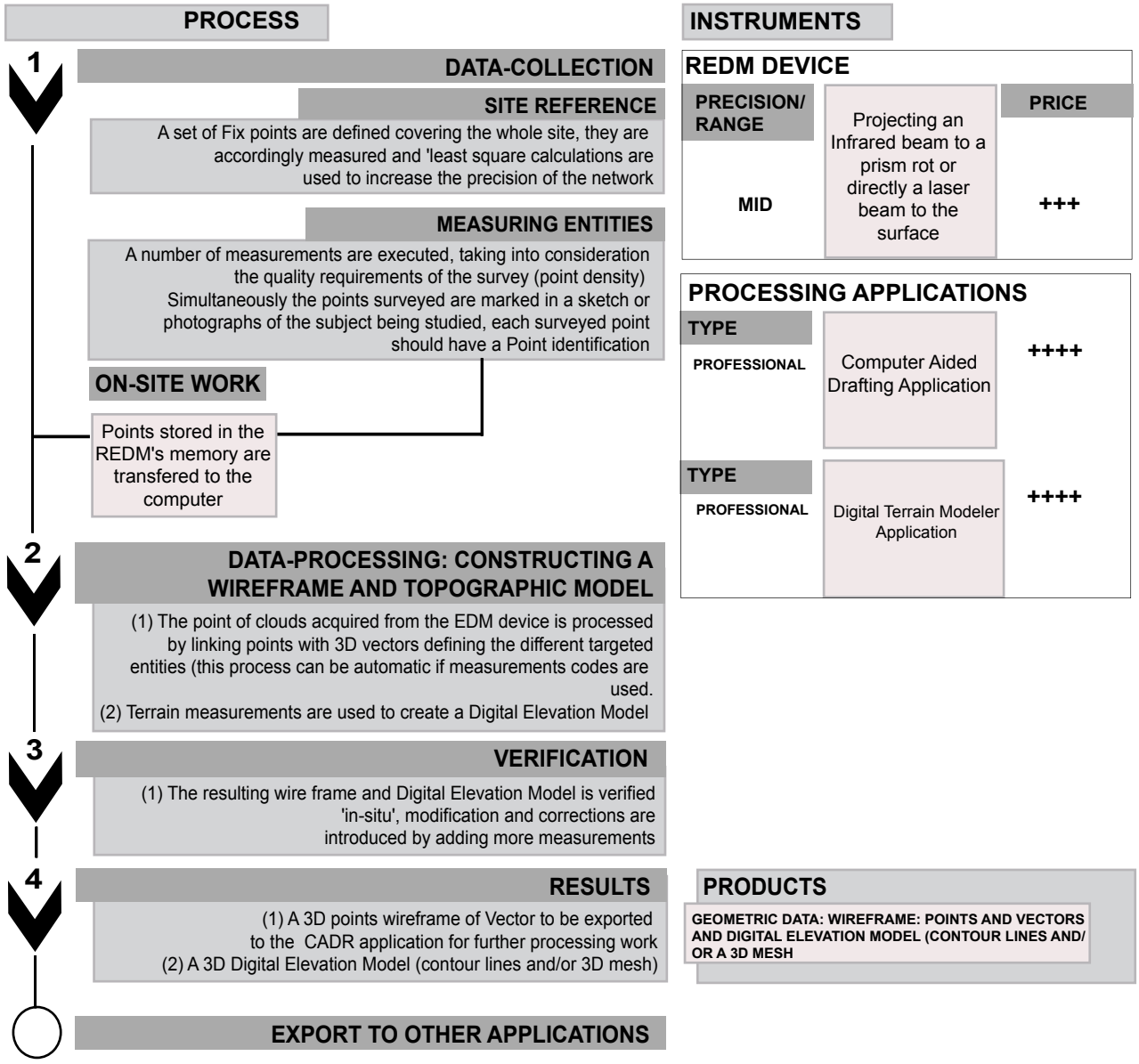
A photograph or multiple overlapping photographs are taken absolute or relative parallel to the plane to be rectified.

Data-processing: the resulting 'plane parallel photography' are photographs with reduced distortion. However, this product can be further processed using a raster image processing application to manually and mechanically reduce the distortion of the photographs by pulling the edges of the image manually (the horizontal and vertical reference should be extracted and clipped as a background in Photoshop to execute this tool).

Moreover, it is possible to use other more advanced software to reduce this distortion (Adobe PhotoShop – AutoCAD Raster Design). This type of tools uses a function called 'rubersheet'. It enables the user to pick a point in photographs and find its correlated position in the CADR application (AutoCAD), after a minimal number of 4 points located in the same plane identified, the programme is capable of stretching the photograph reducing the distortion within the targets assigned.

Subsequently, the image will be vectorized in a CADR application, depending on the

REFLECTORLESS ELECTRONIC DISTANCE MEASUREMENT - DIRECT SURVEY METHODS
(NON-PHOTOGRAPHIC) **-** METHODS FOR DOCUMENTATION IN STUDYING BUILT HERITAGE
METHOD: POINT COLLECTION



VARIABLES

SPEED	PRECISION	RANGE	FIELD OPERABILITY	ADJUSTMENTS CORRECTIONS	TRANSFORMATION POSSIBILITIES
Average 0,15 p/s Depends on speed operator - eng.time	~0.01 - mm. Depends on correct visualisation of the targeted point	2 - 200 m. REDM	Robust Highly Portable on-site Involves extended off-site work and verification only on-site	Advanced Knowledge of surveying	Output is produce in a compatible format: (1) ASCII list of coordinates (2) CADR format

BUDGET	OCCLUSION	CRITICAL ISSUES DEALING WITH BUILT HERITAGE
In Average Suistanable	Multiple Measuring Positions are required to overcome obstacles high areas are difficult to measure (see range)	Time Consuming Generally the precision and observational accuracy depends in the density points collected on-site The data collected is generally limited (time constraint) The range is limited to the reflectorless mode and it is sensitive to the material brightness Suitable for any application in recording built heritage

Chart 2: reflectorless electronic distance measurement: explantion of the methodology and paremeters applied to the Buddhas.

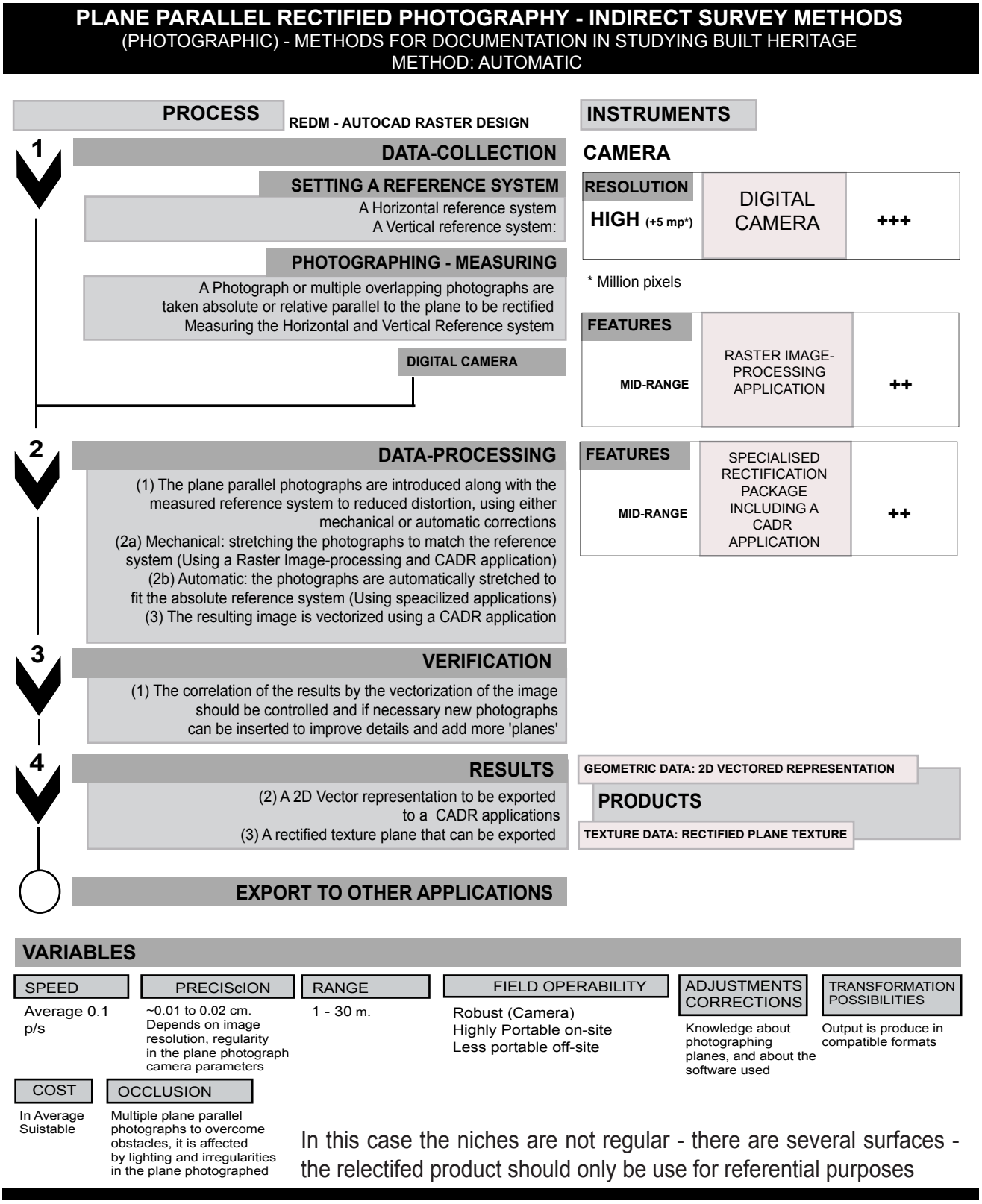


Chart 3: plane parallel rectified photography: explantion of the methodology and paremeters applied to the Buddha.

level of detail required the entities are traced using vectors after the distortion has been corrected an the photograph is place in the absolute position (external orientation).

Verification: the processes of controlling the measurements are performed on-site with the output representation. Control measurements can be made using an REDM device, analogue Theodolithe or Photogrammetry.

Complementary measurements, modification, and corrections should be executed taking new photographs with a higher resolution and implementing more advanced distortion correction tools.

The end product is a rectified photograph vectorized with a planar wire frame of vectors which can be used in combination with other non-photographic and photographic techniques to be enhanced, such as measured hand-survey of details, photogrammetry, or REDM device measurement to further digitise the geometry and texture of the object.

The improvement required to the dataset of the survey can be performing by adding a higher density of points by vectorizing more points onto the photograph and implementing complementary techniques.

Exporting: the output consists of a rectified image of a plane and a planar wire frame of vectors in a CADR drawing format.

Targets: grid system for photographic reference points

A grid of control points was prepared along the structures using the REDM Total Station.

This system ensures a regular reference system to be able to perform an easier and correct rectification of the photographs. This measured representation will be used as frame to automatically rectify the photographs.

Plan parallel aerial photography and automatic rectification

With the help of a lift, photographs are taken covering the whole structure, with an overlapping of at least 30% and covering four targets (control points).

Subsequently, the photographs are scanned and transfer to a programme made to this specific task (PhotoGram Pro) developed by B. Van Genechten (Deptt. ASRO – K.U. Leuven), which can reduce the distortion of the photograph.
Subsequently, AutoCAD Raster design is used to position, scale and fit to the CADR application using the control points measured.

4.7.3 Digital Terrain Model (DTM) applications

Digital terrain model techniques are used for creating a Digital Ground Model (DGM), which is a '*three-dimensional, mathematical representation of the landform and all its features, stored in a computer data base*' (Schofield, W. 2001, p.12)[13].

A DGM is calculated by using on the one hand the information about the topography of the site being studied or and on the other hand numerous computer methods for calculating the Digital Elevation model (DEM), related to calculations aiming at providing different types of representation techniques.

Topographic information required

The information required to create a 'digital elevation model' is related to collecting a numerous set of three-dimensional readings or points from the topography of the site. These points can be collected by digitising directly plotting the topography.

Such as, the field EDM surveying of surface points are measured using a specific interval

(or density).

Calculation method for DTM

The most efficient and common technique is the use of the 'triangular grid method', which is the use of the '*best fit triangles that are formed between the points surveyed*' (Schofield, W. 2001, p.12)[14].

This type of triangular calculation method using the position and height of surveyed points is named a Triangular Irregular Network (TIM). Most DTM applications provide tools for modifying the triangles and heights for improving the representation and provide more accurate results.

Therefore, '*the ground surface therefore comprises a network of triangular planes at various angles*', which can be used for creating a solid model or surface mesh of the landscape, and if necessary the generation of '*contours, sections and levels*', obtained by the '*linear interpolation through the triangles*' (Schofield, W. 2001, p.12)[15].

5. CAPACITY BUILDING: TRAINING GRADUATE STUDENTS IN THE USE OF THE RECORDING TOOLS

During the three-weeks of on-site work, it was possible to further give training to eng. A. Fahmy in the use of the Total Station. This is a continuation of the work carried out during last mission in Herat and Jam in the autumn of 2002.

It is relevant to remain last year proposal for capacity building in the Ministry of Information and Culture in Kabul:

Main goal: creation of a government cell capable of providing services on the documentation of afghan heritage in different fields of action:

Basic objectives:

(1) Creation and implementation of a methodology for a national record system for inventorying and monitoring the actual state of conservation of historical sites across the country, this point can be done in cooperation with the already created database of monuments in Afghanistan by the University of Aachen RWTH in Germany. Training should be concentrated in the use of basic referential tools for recording, such as digital cameras and scanner. Furthermore, the use of Geographic Information System and image databases should be included as an advanced course.

(2) Metric Survey of historic sites, training should be concentrated in the use of electronic distance measurement (EDM) devices (Total station – Laser scanning?), Computer-Aided Drafting application, Digital Terrain Modeler applications, and photogrammetry.

(3) Training to university and other educational institutions in the country, the documentation cell should be encourage to spread knowledge to other institutions, such as department of geodetic engineering, architecture, archaeology, art history, etc. Perhaps a programme on conservation of heritage should be establish in the university that could offer a course on documentation techniques, ranging from creating inventories to the use of metric survey tools.

Equipment required:

Point (2): a set of instruments and software has been already donated to the Ministry of Information of Culture by UNESCO,

however for a second stage, more material should be made available to set up a metric survey cell, including:

Hardware:
PC desktops
A large format Plotter
A server and other items to set up a network.

Software:
Photogrammetric software

Action plan:

The members of this cell have been already selected by UNESCO in cooperation with the Ministry, these persons should have a fluent English capability and sufficient technical knowledge to operate the equipment, therefore the following action plan is proposed:

Phase 1:

- Intensive English course, available locally.
- Computer basic use course, showing the main features of a computer, such as word-processing, spread sheet, and general operation, available locally

Phase 2: Theoretical and practical framework in the use of electronic distance measurement devices and image-based application in preparing a measured dataset of built heritage sites:

- Intensive course on the use of metric survey tools, including EDM devices and simple image-based tools: tentative contents:
  Theoretical framework:
  Introduction to metric survey studies in documenting built heritage
  Use of a REDM Total Station, working with the already donated TCR307 Leica, explaining all the procedures for recording measurements and transferring them to the computer.
  Computer-Aided Drafting and Digital Terrain Modeling processing of measurements course, working with the already donated version of a AutoCAD land desktop v3.
  Simple rectification of plan parallel photography, using a mechanic technique and automatic applications, working with the already donated software of Adobe PhotoShop and Raster Design. As well as, the digital camera.
  Preparing Monitoring forms for a historic site: conclusion combining all the documentation tools explained in the course.
  Practical framework:
  The explanation of each of the contents will be introduce by directly working with case-studies.
- Intensive course of the use of image-based techniques, making emphasis in photogrammetry. This part of the course can be introduce to the trainees in the spring workshop and further developed in a second stage. However if it is relevant, it can be already be integrated in the course.

Moreover, the University of Aachen in Germany and the R. Lemaire International Centre for Conservation (University of Leuven) in Belgium could offer short term internships to some of the trainees to experience the use of these techniques in a different environment.

6. RECOMMENDATIONS: PLANS FOR THE FUTURE

This work could contribute to the Japanese

effort to prepare a scale model of the valley, can be provided in order to endure precise results that can be both used for visitors (broader audience) and the professional work to be carried out in the near future.

Documentation work:

- Preparation of a precise elevation of the east and west fronts of the large and small Buddha with support of engineers.
- Record of adjacent structures to the niches.
- Classification and documentation of major fragments.
- Measurements of chambers currently cover by rubble.

7. CLOSING REMARKS

This report demonstrates that the adapted used of sustainable tools for work in recording historic buildings, with specific variables dealing with the expected quality and precision requirements of the measured representations adjusted to the specific needs of a problem and the desired dissemination product.

Comparative studies using the metric survey representation prepared could yield results to evaluate:

- The structural stability of the different stone fragments and effect of the explosion.
- Preparation of a permanent record of the current condition for future applications.
- Evaluate the development of the conservation works, speed and constraints

Furthermore, capacity building of local experts including the development of local structure that is capable of documenting and caring the heritage of the country should be launch. This cell should have strong links to academic institutions, providing further training to experts in this area.

8. CONTENTS OF REPORT

Daily report
A3 maps
CD-ROMS: 01: Report, images and drawings
02: Complementary digital images

Notes:

[1]Cultural Landscape and Archaeological Remains of the Bamiyan Valley (WHC-UNESCO website) http://whc.unesco.org/sites/208rev.htm (Last visited 11/07/2003)
[2] Knobloch, E. 'The archaeology and architecture of Afghanistan' Tempus, London 2002, pp.88-89
[3] Ibid 2
[4] Cultural Landscape and Archaeological Remains of the Bamiyan Valley (WHC-UNESCO website) http://whc.unesco.org/sites/208rev.htm (Last visited 11/07/2003)
[5] Dupree, N.H. 'An Historical Guide to Afghanistan' Afghan Air Authority, Afghan Tourist Organization, Kabul, 1977, p. 156.
[6] Ibid 2, p. 163.
[7] Cultural Landscape and Archaeological Remains of the Bamiyan Valley (WHC-UNESCO website) http://whc.unesco.org/sites/208rev.htm (Last visited 11/07/2003)
[8] Bruno, A. 'Restoration and beyond: architecture from conservation to conversión: projects and Works by Andrea Bruno (1960-1996)' Mastropietro, M. ed. Edizioni Lybra imagine, Milan 1996. p. 27.
[9] Clark, K. ' Informed Conservation: Understanding historic buildings and their landscape for conservation' English Heritage, London 2001. p. 76.
[10] Ibid 16. p. 83.
[11] Clark, K. ' Informed Conservation: Understanding historic buildings and their landscape for conservation' English Heritage, London 2001. p. 82.
[12] ICOMOS; Guide to Record Historic Buildings; Butterworth Architecture, London 1990. P. 54.
[13] Schofield, W. 'Engineering Surveying', Butterworth & Heinemann, London 2001, p.12.
[14] Ibid 49.
[15] Ibid 49.

391740 391840 391940 392040 392140 392240 392340 392440 392540 392640 392740 392840

3855030 3854930 3854830 3854730 3854630

Small Buddha
(38 m height)

Seated Buddha

Large Buddha
(55 m height)

1 2 3 4 5 6 7 8

Road to town

Bamiyan Cliff including niches of the 38 meter Buddha, seated Buddhas, 55 meter Buddha and surrounding caves

- Main access road (3 lanes)
- Site access road (1 lane)
- Standing structures
- Structures in ruins
- Activity not defined
- Planted fields

1 Party building
2 Local office Min. of Foreign Affairs
3 Local office Min. of Information and Culture
4 Pomp Station
5 Military Headquarters
6 School
7 Cementary
8 Traffic police

0 100 M 200 M

REFERENCE MAP

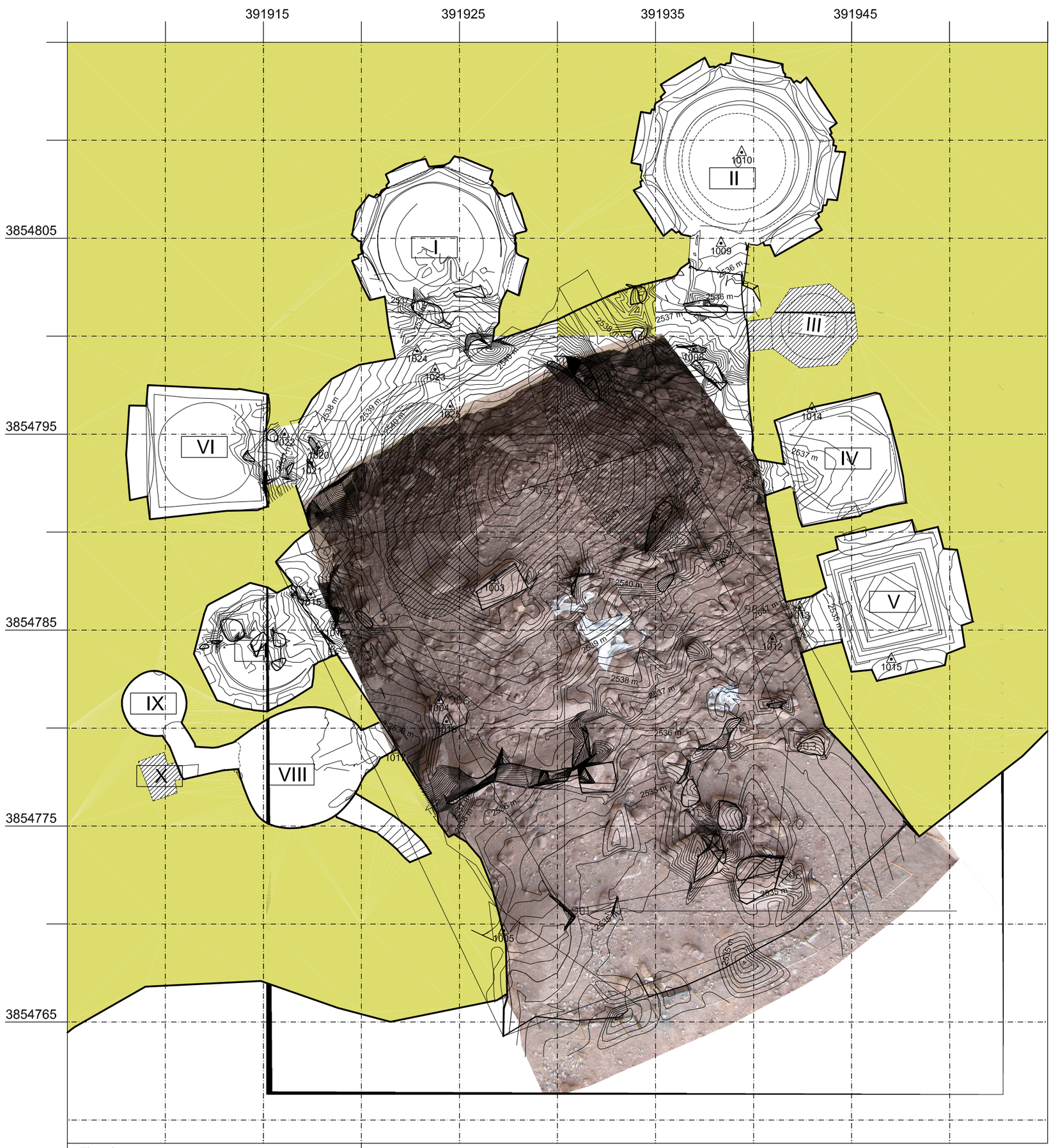
Safeguarding the Cultural Landscape and Archaeological Remains of the Bamiyan Valley

UNESCO

SECTION OF CULTURAL HERITAGE

DESCRIPTION	Context map of the site explaining activities
SCALE	1:3500
FILE NAME	BA0603-001.DWG (AUTOCAD) BA0603-001.PDF (PDF)
DATE	11/07/2003
PAGE	1
SURVEY AND CADR WORK	ENG. A. FAHIM DR. M. SANTANA Q.

METRIC SURVEY TECHNIQUES:
REDM Total Station TCR307 Leica
AutoCAD Land Desktop 3 Precision: 0.03 to 0.1 m



Fixpoints:

ID	East (m)	North (m)	Height (m)
1003	391926.776	3854787.557	2542.454
1004	391923.952	3854781.431	2540.398
1005	391927.119	3854769.713	2536.241
1006	391944.392	3854779.543	2536.541
1007	391914.707	3854772.052	2561.872
1008	391936.939	3854799.333	2538.359
1009	391938.34	3854804.746	2535.948
1010	391939.39	3854809.384	2535.31
1011	391935.116	3854811.832	2536.586
1012	391940.961	3854784.557	2536.655
1013	391942.338	3854786.168	2536.611
1014	391942.975	3854796.303	2537.918
1015	391917.388	3854786.827	2538.877
1016	391918.685	3854785.283	2539.241
1017	391921.765	3854778.877	2538.483
1018	391924.338	3854780.339	2539.874
1020	391917.818	3854794.352	2538.883
1021	391917.45	3854793.509	2538.753
1022	391916.081	3854794.995	2538.005
1023	391923.756	3854798.313	2539.909
1024	391922.841	3854799.246	2539.088
1025	391924.525	3854796.419	2541.242
1026	391927.841	3854804.57	2537.381

These areas have been digitized from a plan by Fango, R. 'Dossier Afghanistan' ANA FKH 32, Dec 2001. P. 30. Currently they are cover by rubble

0 10 M 20 M

Contour Interval= minor 0.5 m major 2 m.
Grid interval: 5 m

Technical specifications of the digital terrain model:
Number of triangles: 8050
Mean elevation: 2537.73 m
Minimum triangle area: 0.00 m
Maximum triangle area: 7.92 m
2D surface area: 892.27 m2
3D surface area: 1241.51 m3
Minimum grade: 0.60 %
Maximum grade: 1409435.86 %
Average grade: 472.54 %
Cut Volume: 5,147 m3
Fill Volume: 83.74 m3
Net: 78,6 m3
Reference datum for volume calculation: 2535.35 m.

Large Buddha

Safeguarding the Cultural Landscape and Archaeological Remains of the Bamiyan Valley

UNESCO

SECTION OF CULTURAL HERITAGE

DESCRIPTION	Detail - Ground plan Fixpoints -Rectified image
SCALE	1:200
FILE NAME	BA0306-004.DWG (AUTOCAD) BA0306-004.PDF (PDF)
DATE	03/07/2003
PAGE	4
SURVEY AND CADR WORK	ENG. A. FAHIM DR. M. SANTANA Q.

METRIC SURVEY TECHNIQUES:
REDM Total Station TCR307 Leica — Adobe PhotoShop - ACAD Raster Design
AutoCAD Land Desktop 3 — Precision: 0.03 to 0.1 m

392715 392725 392735 392745

3855005

3855000

3854995

2569,5 m

2555 m 2554 m 2555 m 2554 m 2553 m 2552 m 2551 m 2550 m 2552 m

501 502 503 504 505 506 507

Fixpoints

501	392734.888	3854999.213	2555.497
502	392737.091	3854992.717	2552.088
503	392724.975	3854994.545	2552.358
504	392740.449	3854998.160	2554.965
505	392735.386	3855010.607	2552.562
506	392734.916	3855008.160	2551.949
507	392734.373	3855005.702	2552.626
509	392746.435	3854990.107	2549.571

These areas have been digitized from a plan by Fango, R. 'Dossier Afghanistan' ANA FKH 32, Dec 2001. P. 63. Currently they are cover by rubble

0 10 M 20 M

Contour Interval: major 1 - minor 0.2
Grid Interval: 5 m.

Small Buddha

Safeguarding the Cultural Landscape and Archaeological Remains of the Bamiyan Valley

UNESCO

SECTION OF CULTURAL HERITAGE

DESCRIPTION	Detail map Level 2 - chambers
SCALE	1:100
FILE NAME	BA0306-011.DWG (AUTOCAD) BA0306-011.PDF (PDF)
DATE	11/07/2003
PAGE	11
SURVEY AND CADR WORK	ENG. A. FAHIM DR. M. SANTANA Q.

METRIC SURVEY TECHNIQUES:
REDM Total Station TCR307 Leica
AutoCAD Land Desktop 3 Precision: 0.03 to 0.1 m